BAB

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AGRICULTURAL MEMORANDUM NO. 980

Further examination of the Hampshire epidemic of Foot-and-Mouth disease, 1967

By J Gloster

INTRODUCTION

The speed at which outbreaks of Foot-and-Mouth disease (FMD) are brought under control is influenced by how effectively the limited veterinary and technical resources are deployed by the Ministry of Agriculture, Fisheries and Food (MAFF). During any outbreak of FMD the model described by Gloster and others (1981) is used to predict the airborne spread of disease from virus emitted by affected livestock. When the predicted area for likely secondary infections is small, as was the case in the 1981 Isle of Wight FMD outbreak (Donaldson and others, 1982), MAFF have sufficient staff to deploy to keep further disease spread to a minimum. However, when the predicted area of possible secondary infections is large, the situation becomes far more problematic, because of MAFF's limited resources. It would then be advantageous to define which individual farms are at the greatest risk and then deploy the resources accordingly.

Experience gained from past disease outbreaks suggests that the risk of airborne disease spread to a farm increases with the size of its cattle herd (Gloster and others, 1982). Laboratory work suggests that the level of challange (ie the dosage to which an animal is exposed in a given time period) also influences the likelihood of infection (Hyslop, 1973; Eskildsen, 1969). Both of these aspects are examined in this memorandum and the 1967 Hampshire epidemic of FMD is used to test these observations. In addition the results of some theoretical calculations on the probability of airborne infection are presented and the results compared with those from the Hampshire epidemic.

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1967 HAMPSHIRE EPIDEMIC

Sources of information

1. The location and number of livestock held on farms in the vicinity of Fareham, Hampshire at the time of the epidemic have been supplied by MAFF.

2. Weather data were obtained from Southampton (Eastleigh) and Thorney Island observing stations.

3. The epidemic has already been described and analysed by numerous workers. Particular reference in this memorandum has been made to the papers by Sellers and Forman (1973) and Gloster and others (1981).

ANALYSIS OF THE EPIDEMIC

The Hampshire epidemic started in the Portsmouth area on January 5th, 1967 and lasted until February 3rd. Disease was confirmed on 29 farms and 2774 cattle, 414 sheep, 4708 pigs and 6 goats were slaughtered. Sellers and Forman (1973) suggested that Fareham abattoir was the centre for much of the disease spread in the area.

138 farms with cattle, the most susceptible of livestock to airborne infection, were situated in the vicinity of Fareham abattoir (Figure 1). In this article each farm has been allocated a reference number; numbers 1-117 identify farms which remained unaffected during the epidemic; numbers 201-229 indicate confirmed disease outbreaks (the last two digits refer to the order in which disease was reported to MAFF ie Fareham abattoir /209/ was the ninth reported case).

Sellers and Forman (1973) suggested that fifteen outbreaks (201, 202, 203, 205, 207, 208, 210, 211, 212, 215, 219, 221, 222, 223, and 226) were caused by virus released into the atmosphere from Fareham abattoir. The number of cattle on each of these holdings and those which remained unaffected are given in Table 1.

For each of the farms in Table 1 the daily inhaled dosage of virus was estimated using the model described by Gloster and others (1981). The values for virus emission and the period over which emission occurred were those suggested by Gloster and others (1981) and Sellers and Forman (1973).

RESULTS

Figure 2 shows the frequency distribution of farms, by size of herd, used in this study. It can be seen that there was a large number of small farms in the area and only a few with 100 or more head of cattle. Confirmed outbreaks occurred over almost the full range of herd sizes.

Table 2 gives inhaled dosage (infectious units per day per cow) for each of the farms examined for the period 29th December 1966 to January 9th 1967. The maximum inhaled daily dosage during this period for each of the farms is given in Figure 3 (for clarity confirmed outbreaks have been circled). For farms on which disease was confirmed the analysis given in Figure 3 was limited to the 3-10 day infection period defined by Sellers and Forman (1973). The majority of farms affected had large herds that were exposed to large amounts of airborne virus. No infection occurred when the estimated level of challange was less than 1 infectious unit per day per cow. Many small units escaped disease even when they had been subjected to large quantities of virus.

CALCULATION OF THE PROBABILITY OF INFECTION

Gloster and Field (1982) determined an expression to estimate the probability, P, that one or more birds which inhaled airborne Newcastle disease virus would subsequently become infected as:-

$$P = 1 - e^{-n_o Nrtm}$$

where n_o = Atmospheric concentration of virus (m^{-3})

N = Number of birds inhaling virus

r = Breathing rate of a bird (m^3 sec^{-1})

t = Length of time birds inhale virus (sec)

m = Probability of an individual particle causing infection.

This expression can also be used to estimate the probability of infection in cattle exposed to airborne FMD virus. The only modification required is to substitute the breathing rate of a cow for that of a bird.

Daily values for the airborne challange ($n_o rt$) for cattle during the 1967 Hampshire epidemic are given in Table 2, but before P can be calculated a value for m is required. This has been estimated from the data presented in Table 2 and plotted in Figure 3 using the following method:-

1. Three areas each containing both confirmed and unaffected farms were chosen (Figure 4).

2. For each of the three areas (1-3) the ratio of numbers of affected to unaffected premises, the medium herd size and the medium dosage was determined. These values were substituted into the probability equation and values of m found.

The m values obtained were 0.91×10^{-3}, 1.1×10^{-3} and 0.84×10^{-3}. The probability equation was then resolved to find values for the level of challange ($n_o rt$) for a range of herd sizes (N = 1 to 150) and a range of probabilities of infection (P = 0.9 to 0.01). A constant value of m (1.0×10^{-3}) was used.

Figure 5 presents the results from these calculations. Lines of equal probability of infection, P, as a function of herd size and level of challange are plotted. For a given herd size P increases as the level of challange rises and for a given level of challange P increases with herd size.

It was observed earlier that no infection occurred when the airborne challange was less than 1 infectious unit per day per cow. This threshold value was introduced into the calculations to produce the probability curves shown in Figure 6. If the curves of Figure 5 are compared with those of Figure 6 the most noticeable difference occurs when the level of challange only just exceeds the threshold value and the herd size is large; the probability of infection decreases considerably.

Figures 7 and 8 superimpose the results from this section on to those obtained in the previous section. The evidence presented in these figures shows that the calculated probabilities are broadly consistent with the observed pattern of infection; in particular it is seen that probabilities around 0.5 provide a reasonable specification of the region in which one would expect an overlap of points representing both disease free and infected premises.

SUGGESTED OPERATIONAL PROCEDURE TO IDENTIFY FARMS AT GREATEST RISK TO AIRBORNE DISEASE SPREAD

1. Obtain the location and herd sizes in the vicinity of a disease outbreak.

2. Run the FMD prediction model.

3. For each of the farms plot herd size v inhaled dosage.

4. Using the data given in Figure 5 or 6 ascertain, in descending order of importance, the farms which are at risk to airborne disease transmission ie farms with a high value at P are at greater risk than those with a low value.

5. When two herds have the same probability of infection the larger unit is of greater importance because it is potentially a greater source for further disease spread.

CONCLUSIONS

1. The analysis has supported the observations from past disease outbreaks and from laboratory work that the probability of infection is a function of the number of cattle exposed to virus and the degree to which they are challanged; this work has quantified this relationship.

2. The evidence presented suggests that a threshold dosage of 1 infectious unit per day per cow is required to initiate infection.

3. The results suggest a way in which, in future disease outbreaks, the risk of airborne spread to individual units in the vicinity may be assessed, provided the size and distribution of herds in the areas are known.

ACKNOWLEDGMENTS

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TABLE 1 THE NUMBER OF CATTLE ON EACH OF THE FARMS USED IN THIS STUDY

Farm No.	Number of cattle
1	5
2	33
3	68
4	17
5	17
6	6
7	7
8	10
9	71
10	10
11	13
12	9
13	3
14	11
15	1
16	143
17	66
18	7
19	16
20	5
21	1
22	8
23	58
24	10
25	23
26	6
27	7
28	11
29	13
30	3
31	55
32	60
33	4
34	15
35	1
36	4
37	14
38	75
39	1
40	13
41	17

Farm No.	Number of cattle
42	2
43	3
44	16
45	13
46	2
47	57
48	35
49	50
50	14
51	22
52	26
53	40
54	13
55	8
56	21
57	10
58	9
59	26
60	21
61	5
62	8
63	4
64	2
65	19
66	16
67	18
68	60
69	6
70	1
71	34
72	10
73	34
74	12
75	53
76	29
77	48
78	8
79	44
80	13
81	24
82	16

Farm No.	Number of cattle
83	22
84	11
85	53
86	5
87	22
88	12
89	5
90	10
91	87
92	104
93	24
94	37
95	12
96	4
97	79
98	1
99	77
100	139
101	39
102	13
103	11
104	11
105	15
106	81
107	27
108	28
109	10
110	86
111	15
112	64
113	14
114	28
115	115
116	7
117	97

Farm No.	Number of cattle
201	86
202	123
203	93
205	139
207	45
208	130
210	106
211	66
212	84
215	69
219	97
221	14
222	49
223	49
226	94

Table 2

TOTAL DAILY INHALED DOSAGE (INFECTIOUS UNITS per day per cow)

FARM NUMBER	NUMBER OF CATTLE	DECEMBER 1966			JANUARY 1967								
		29	30	31	1	2	3	4	5	6	7	8	9
1	5	0.0	0.255	0.342	0.0	0.0	0.0	0.0	0.0	0.012	0.000	0.0	0.0
2	33	0.0	4.885	0.480	0.0	0.0	0.0	0.0	0.0	0.038	0.000	0.0	0.0
3	68	0.0	0.534	0.791	0.0	0.0	0.0	0.0	0.0	0.135	0.001	0.0	0.0
4	17	0.0	4.885	0.480	0.0	0.0	0.0	0.0	0.0	0.038	0.000	0.0	0.0
5	17	0.0	0.255	0.342	0.0	0.0	0.0	0.0	0.0	0.012	0.000	0.0	0.0
6	6	0.0	0.533	0.546	0.0	0.0	0.0	0.0	0.0	0.002	0.001	0.0	0.0
7	7	0.0	0.533	0.546	0.0	0.0	0.0	0.0	0.0	0.002	0.001	0.0	0.0
8	10	0.0	0.001	0.000?	0.0	0.0	0.0	0.0	0.0	0.0	0.046	0.0	0.0
9	71	0.0	0.001	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.046	0.0	0.0
10	10	0.0	0.001	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.046	0.0	0.0
11	13	0.0	0.000	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.137	0.0	0.0
12	9	0.0	0.000	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.137	0.0	0.0
13	3	0.0	0.000	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.179	0.0	0.0
14	11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.112	0.0	0.0
15	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.094	0.0	0.0
16	143	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.257	0.0	0.0
17	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.392	0.0	0.0
18	66	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.392	0.0	0.0
19	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.877	0.0	0.0
20	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.877	0.0	0.0
21	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.609	0.0	0.0
22	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.505	0.000	0.0
23	58	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.505	0.000	0.0
24	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.505	0.000	0.0
25	23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.505	0.000	0.0
26	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.857	0.010	0.0
27	72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.857	0.010	0.0
28	11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.532	0.004	0.0
29	13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.532	0.004	0.0
30	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.564	0.144	0.0
31	55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.329	0.318	0.0
32	60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.329	0.318	0.0
33	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.423	2.874	0.000
34	15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.140	1.765	0.000
35	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.813	2.093	0.005
36	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.0	0.644	2.983	0.017
37	14	0.0	0.0	0.0	0.0	0.000	0.0	0.0	0.000	0.0	0.245	2.307	0.079
38	75	0.0	0.0	0.0	0.0	0.000	0.0	0.0	0.000	0.0	0.095	1.017	0.029
39	1	0.0	0.003	0.0	0.0	0.155	0.000	0.000	0.302	0.006	0.005	1.888	2.045
40	13	0.0	0.0	0.0	0.0	0.014	0.0	0.0	0.007	0.00 6	0.030	2.844	0.323
41	17	0.0	0.0	0.0	0.0	0.003	0.0	0.0	0.001	0.000	0.006	1.493	0.144
42	2	0.0	0.0	0.0	0.0	0.003	0.0	0.0	0.001	0.000	0.006	1.493	0.144
43	3	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.000	0.0	0.003	1.196	0.109
44	13	0.000	0.167	0.089	1.136	0.494	0.100	0.065	0.025	0.323	0.124	0.0	0.030
45	13	0.000	0.167	0.089	1.136	0.494	0.100	0.065	0.025	0.323	0.124	0.0	0.030
46	2	0.026	0.162	0.584	0.616	0.265	0.051	0.031	0.000	0.324	0.001	0.0	0.011
47	57	0.018	0.135	0.470	0.449	0.201	0.032	0.020	0.000	0.186	0.000	0.0	0.007
48	35	0.012	0.118	0.385	0.340	0.158	0.021	0.013	0.000	0.159	0.000	0.0	0.005
49	50	0.009	0.105	0.324	0.263	0.127	0.015	0.008	0.000	0.138	0.000	0.0	0.003
50	14	0.009	0.105	0.324	0.263	0.127	0.015	0.008	0.000	0.138	0.000	0.0	0.003
51	22	0.009	0.105	0.324	0.263	0.127	0.015	0.008	0.000	0.138	0.000	0.0	0.003
52	26	0.006	0.094	0.278	0.208	0.104	0.011	0.006	0.000	0.123	0.000	0.0	0.002
53	40	0.006	0.094	0.278	0.208	0.104	0.011	0.006	0.000	0.123	0.000	0.0	0.002
54	13	0.006	0.094	0.278	0.208	0.104	0.011	0.006	0.000	0.123	0.000	0.0	0.002
55	8	0.006	0.094	0.278	0.208	0.104	0.011	0.006	0.000	0.123	0.000	0.0	0.002
56	21	0.070	2.489	1.273	11.784	0.043	1.526	0.096	0.0	1.401	0.0	0.0	0.000

Table 2 continued

57	10	0.070	2.489	1.273	11.784	0.043	1.526	0.096	0.0	1.401	0.0	0.0	0.000
58	8	0.070	2.489	1.273	11.784	0.043	1.526	0.096	0.0	1.401	0.0	0.0	0.000
59	26	0.070	2.489	1.273	11.784	0.043	1.526	0.096	0.0	1.401	0.0	0.0	0.000
60	21	0.070	2.489	1.273	11.784	0.043	1.526	0.096	0.0	1.401	0.0	0.0	0.000
61	5	0.070	2.489	1.273	11.784	0.043	1.526	0.096	0.0	1.401	0.0	0.0	0.000
62	8	0.070	2.489	1.273	11.784	0.043	1.526	0.096	0.0	1.401	0.0	0.0	0.000
63	4	0.070	2.489	1.273	11.784	0.043	1.526	0.096	0.0	1.401	0.0	0.0	0.000
64	2	0.070	2.489	1.273	11.784	0.043	1.526	0.096	0.0	1.401	0.0	0.0	0.000
65	19	0.070	2.489	1.273	11.784	0.043	1.526	0.096	0.0	1.401	0.0	0.0	0.000
66	16	0.299	0.481	2.002	23.564	0.509	0.092	0.179	0.000	4.066	0.000	0.0	0.021
67	18	0.315	0.491	0.931	0.629	0.267	0.054	0.132	0.0	0.353	0.0	0.0	0.004
68	60	0.091	2.836	1.624	14.599	0.072	1.758	0.112	0.0	1.606	0.0	0.0	0.001
69	6	0.091	2.836	1.624	14.599	0.072	1.759	0.112	0.0	1.606	0.0	0.0	0.001
70	1	0.091	2.836	1.624	14.599	0.072	1.758	0.112	0.0	1.606	0.0	0.0	0.001
71	34	0.079	2.646	1.427	13.028	0.055	1.630	0.097	0.0	1.493	0.0	0.0	0.001
72	10	0.091	2.836	1.624	14.599	0.072	1.758	0.112	0.0	1.606	0.0	0.0	0.001
73	34	0.106	3.074	1.883	16.911	0.097	2.002	0.131	0.0	1.749	0.0	0.0	0.002
74	12	0.106	3.074	1.883	16.911	0.097	2.002	0.131	0.0	1.749	0.0	0.0	0.002
75	53	0.106	3.074	1.883	16.811	0.097	2.002	0.131	0.0	1.749	0.0	0.0	0.002
76	29	0.051	0.087	0.130	0.140	0.037	0.015	0.061	0.0	0.084	0.0	0.0	0.000
77	48	0.051	0.087	0.130	0.140	0.037	0.015	0.061	0.0	0.084	0.0	0.0	0.000
78	8	0.067	0.114	0.192	0.205	0.056	0.027	0.077	0.0	0.110	0.0	0.0	0.000
79	44	0.117	0.156	0.381	0.324	0.089	0.050	0.101	0.0	0.151	0.0	0.0	0.001
80	13	0.067	0.114	0.192	0.205	0.056	0.027	0.077	0.0	0.110	0.0	0.0	0.000
81	24	0.117	0.156	0.381	0.324	0.089	0.050	0.101	0.0	0.151	0.0	0.0	0.001
82	16	0.200	0.131	0.165	0.008	0.016	0.000	0.029	0.0	0.110	0.0	0.0	0.000
83	22	0.095	0.081	0.069	0.002	0.005	0.000	0.017	0.0	0.051	0.0	0.0	0.0
84	11	0.136	0.102	0.105	0.004	0.009	0.000	0.022	0.0	0.074	0.0	0.0	0.000
85	53	2.394	0.156	2.600	0.000	0.001	0.0	0.002	0.0	0.371	0.0	0.0	0.0
86	5	2.731	0.190	3.122	0.000	0.002	0.0	0.003	0.0	0.445	0.0	0.0	0.0
87	22	2.149	0.132	2.225	0.000	0.000	0.0	0.001	0.0	0.318	0.0	0.0	0.0
88	12	2.394	0.156	2.600	0.000	0.001	0.0	0.002	0.0	0.371	0.0	0.0	0.0
89	5	3.082	0.322	4.629	0.001	0.009	0.0	0.011	0.0	0.732	0.0	0.0	0.0
90	10	3.082	0.322	4.629	0.001	0.009	0.0	0.011	0.0	0.732	0.0	0.0	0.0
91	87	2.731	0.190	3.122	0.000	0.002	0.0	0.003	0.0	0.445	0.0	0.0	0.0
92	104	1.463	0.680	5.223	0.000	0.001	0.0	0.007	0.0	0.702	0.001	0.0	0.0
93	24	0.726	0.385	2.941	0.000	0.000	0.0	0.002	0.0	0.309	0.000	0.0	0.0
94	37	0.038	0.215	0.976	0.0	0.0	0.0	0.000	0.0	0.419	0.018	0.0	0.0
95	12	0.000	0.091	0.057	0.0	0.0	0.0	0.0	0.0	1.346	0.262	0.0	0.0
96	4	0.000	0.091	0.057	0.0	0.0	0.0	0.0	0.0	1.346	0.262	0.0	0.0
97	79	0.0	0.038	0.005	0.0	0.0	0.0	0.0	0.0	1.472	0.618	0.0	0.0
98	1	0.0	0.039	0.005	0.0	0.0	0.0	0.0	0.0	1.472	0.618	0.0	0.0
99	77	0.0	19.121	0.605	0.0	0.0	0.0	0.0	0.0	8.522	1.509	0.0	0.0
100	139	0.0	0.057	0.033	0.0	0.0	0.0	0.0	0.0	1.365	0.156	0.0	0.0
101	39	0.0	0.057	0.033	0.0	0.0	0.0	0.0	0.0	1.365	0.156	0.0	0.0
102	13	0.0	0.215	0.301	0.0	0.0	0.0	0.0	0.0	0.716	0.018	0.0	0.0
103	11	0.041	0.071	0.091	0.101	0.025	0.009	0.051	0.0	0.067	0.0	0.0	0.000
104	11	0.034	0.060	0.064	0.075	0.017	0.005	0.043	0.0	0.054	0.0	0.0	0.000
105	15	0.041	0.071	0.091	0.101	0.025	0.009	0.051	0.0	0.067	0.0	0.0	0.000
106	81	0.034	0.060	0.064	0.075	0.017	0.005	0.043	0.0	0.054	0.0	0.0	0.000
107	27	0.034	0.060	0.064	0.075	0.017	0.005	0.043	0.0	0.054	0.0	0.0	0.000
108	28	0.029	0.052	0.046	0.057	0.012	0.003	0.037	0.0	0.045	0.0	0.0	0.000
109	10	0.029	0.052	0.046	0.057	0.012	0.003	0.037	0.0	0.045	0.0	0.0	0.000
110	86	0.041	0.071	0.091	0.101	0.025	0.009	0.051	0.0	0.067	0.0	0.0	0.000
111	15	0.095	0.081	0.069	0.002	0.005	0.000	0.017	0.0	0.051	0.0	0.0	0.0
112	64	0.049	0.059	0.032	0.001	0.002	0.0	0.011	0.0	0.027	0.0	0.0	0.0
113	14	0.049	0.059	0.032	0.001	0.002	0.0	0.011	0.0	0.027	0.0	0.0	0.0
114	28	0.029	0.052	0.046	0.057	0.012	0.003	0.037	0.0	0.045	0.0	0.0	0.000
115	115	0.029	0.052	0.046	0.057	0.012	0.003	0.037	0.0	0.045	0.0	0.0	0.000
116	7	0.029	0.052	0.046	0.057	0.012	0.003	0.037	0.0	0.045	0.0	0.0	0.000

Table 2 continued

117	97	0.029	0.052	0.046	0.057	0.012	0.003	0.037	0.0	0.045	0.0	0.0	0.000
201	86	0.079	2.644	1.437	13.029	0.055	1.630	0.097	0.0	1.493	0.0	0.0	0.001
202	123	0.127	3.384	2.241	10.909	0.135	2.370	0.158	0.0	1.923	0.0	0.0	0.003
203	93	0.172	2.091	9.741	0.636	0.951	0.001	0.412	0.0	3.137	0.0	0.0	0.001
203	93	2.434	2.051	6.120	9.260	1.891	0.028	0.599	0.000	2.206	0.000	0.0	0.050
203	93	1.354	2.128	9.775	103.645	3.227	1.684	1.006	0.002	17.219	0.009	0.0	0.194
205	139	0.511	0.900	3.530	39.740	1.030	0.325	0.358	0.000	6.778	0.001	0.0	0.052
207	45	0.020	9.724	1.637	6.920	4.743	2.241	0.951	0.234	1.691	1.086	0.0	0.302
208	130	0.208	4.422	3.599	31.507	0.300	3.746	0.262	0.000	2.874	0.000	0.0	0.010
210	105	0.159	3.907	2.755	24.406	0.195	2.904	0.198	0.0	2.214	0.000	0.0	0.005
211	66	0.209	0.461	2.002	22.564	0.509	0.092	0.170	0.000	4.066	0.000	0.0	0.021
212	84	0.070	2.489	1.273	11.794	0.043	1.526	0.096	0.0	1.401	0.0	0.0	0.000
215	69	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.454	0.038	0.0
219	97	0.0	0.0	0.0	0.0	0.006	0.0	0.0	0.003	0.000	0.013	1.970	0.204
221	14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.815	0.016	0.0
222	49	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.815	0.016	0.0
223	49	0.0	0.864	0.200	0.001	10.953	2.149	0.520	8.592	6.166	0.000	0.000	10.713
226	94	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.468	0.000	0.0

[ ] 3-10 day infection period (Sellers and Foreman 1973)

Figure 1 Location of Livestock in the Fareham Area, 1967

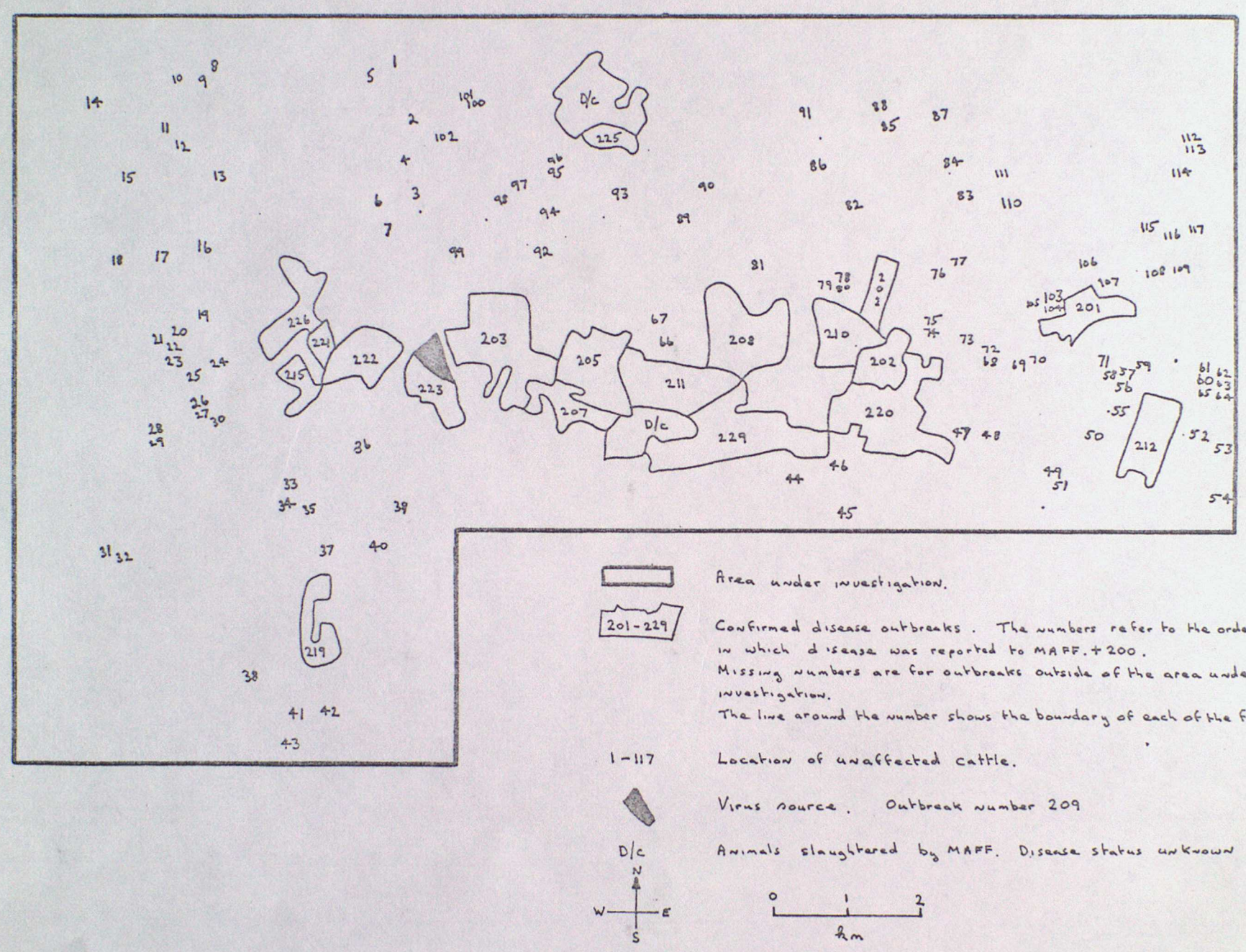
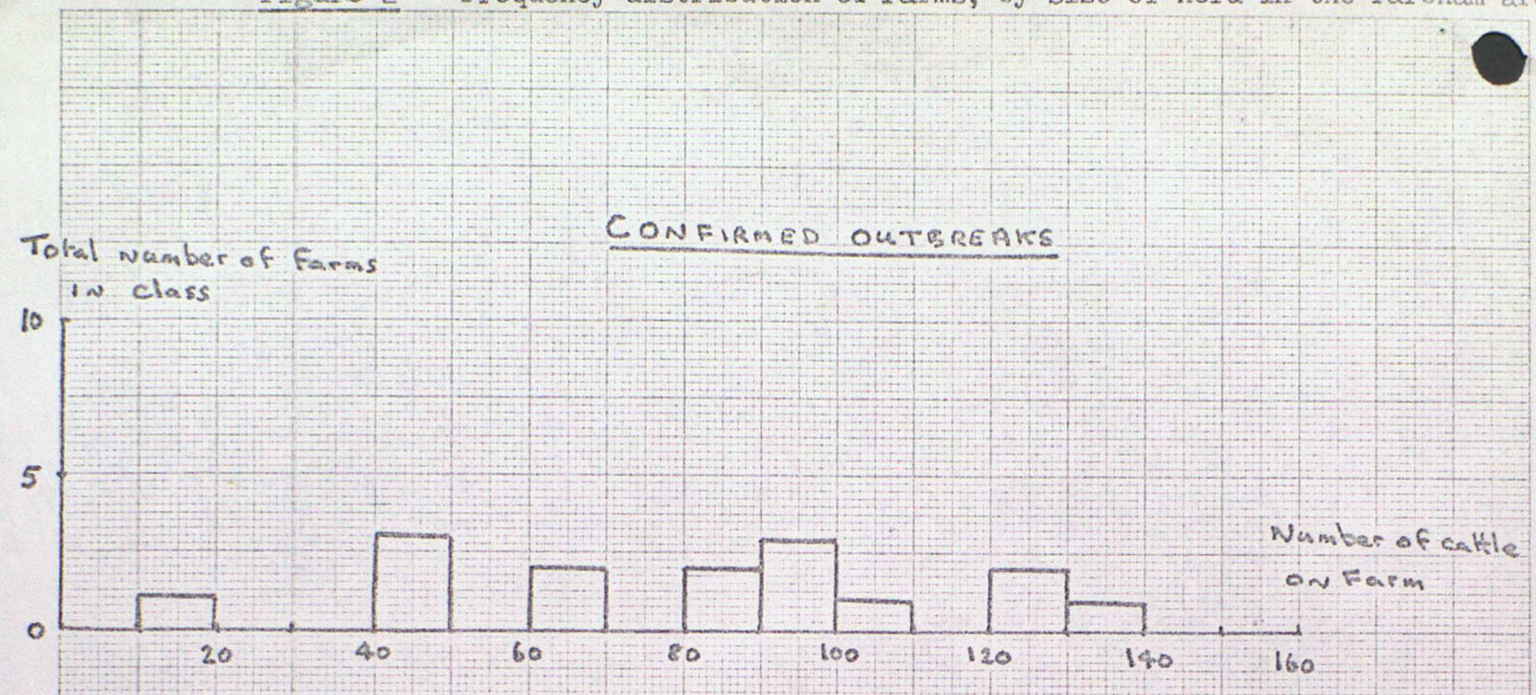


Figure 2 Frequency distribution of farms, by size of herd in the Fareham area



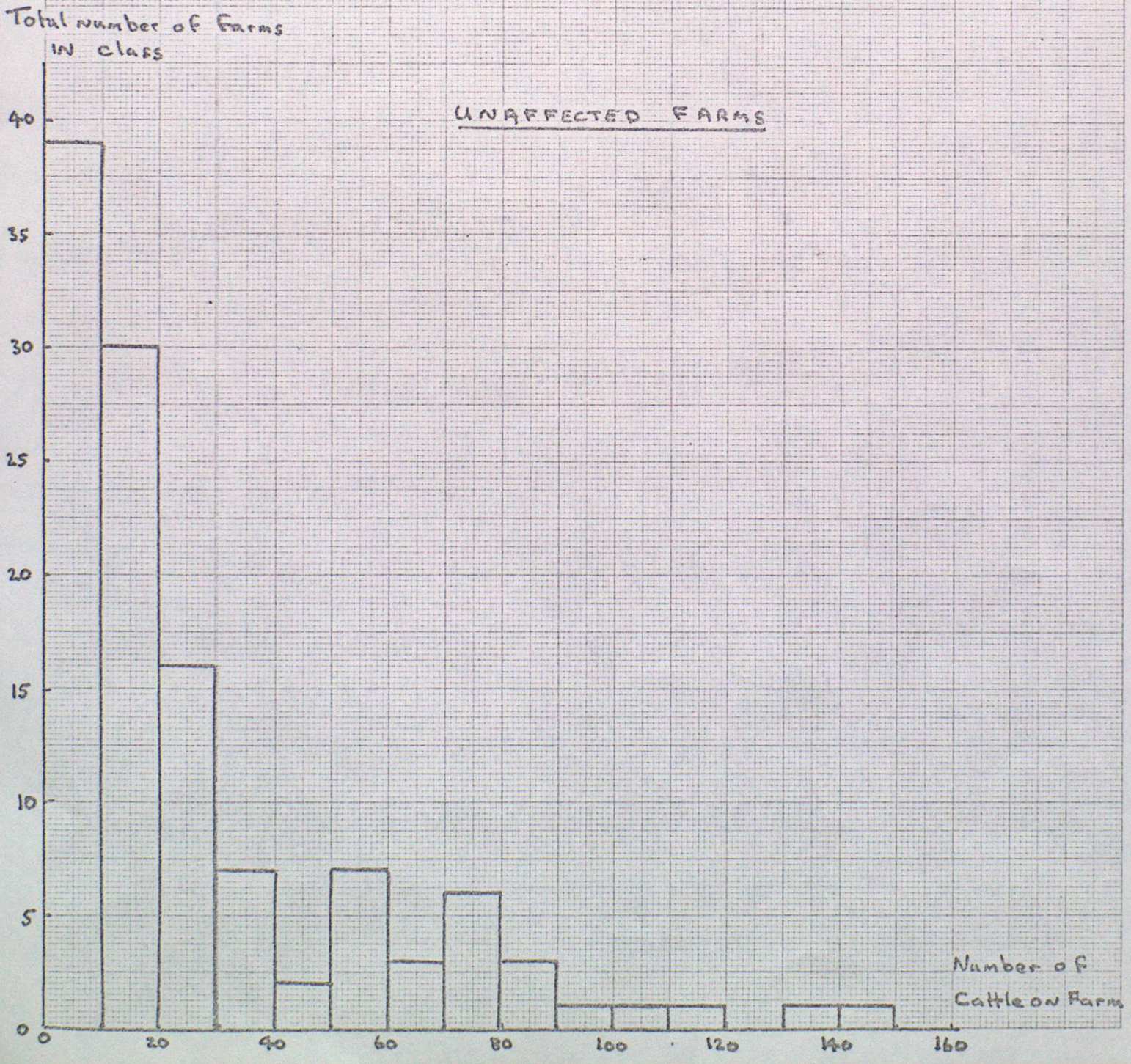


Figure 3 Maximum inhaled daily dosage

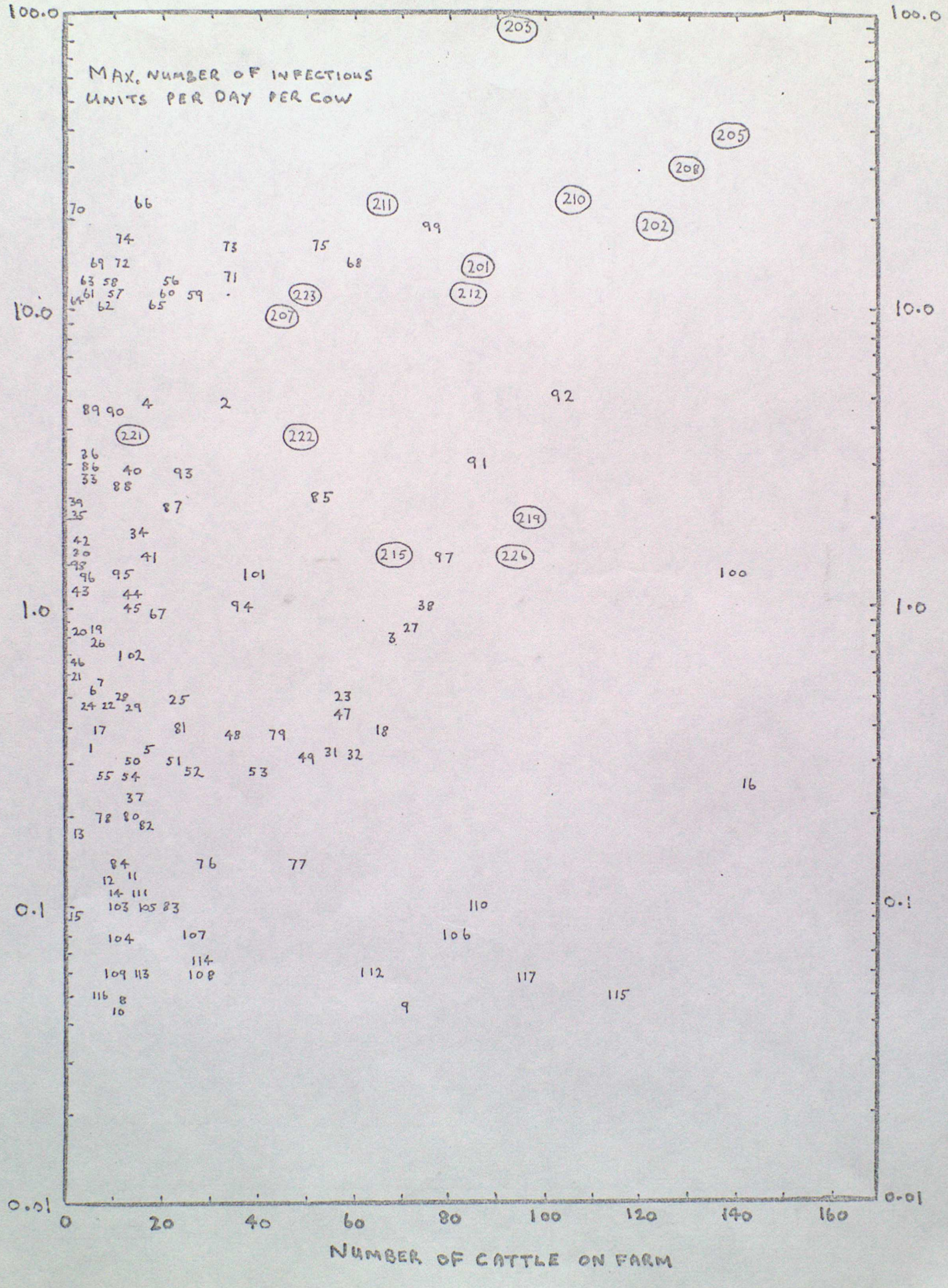


Figure 4 Areas used to determine a value for m

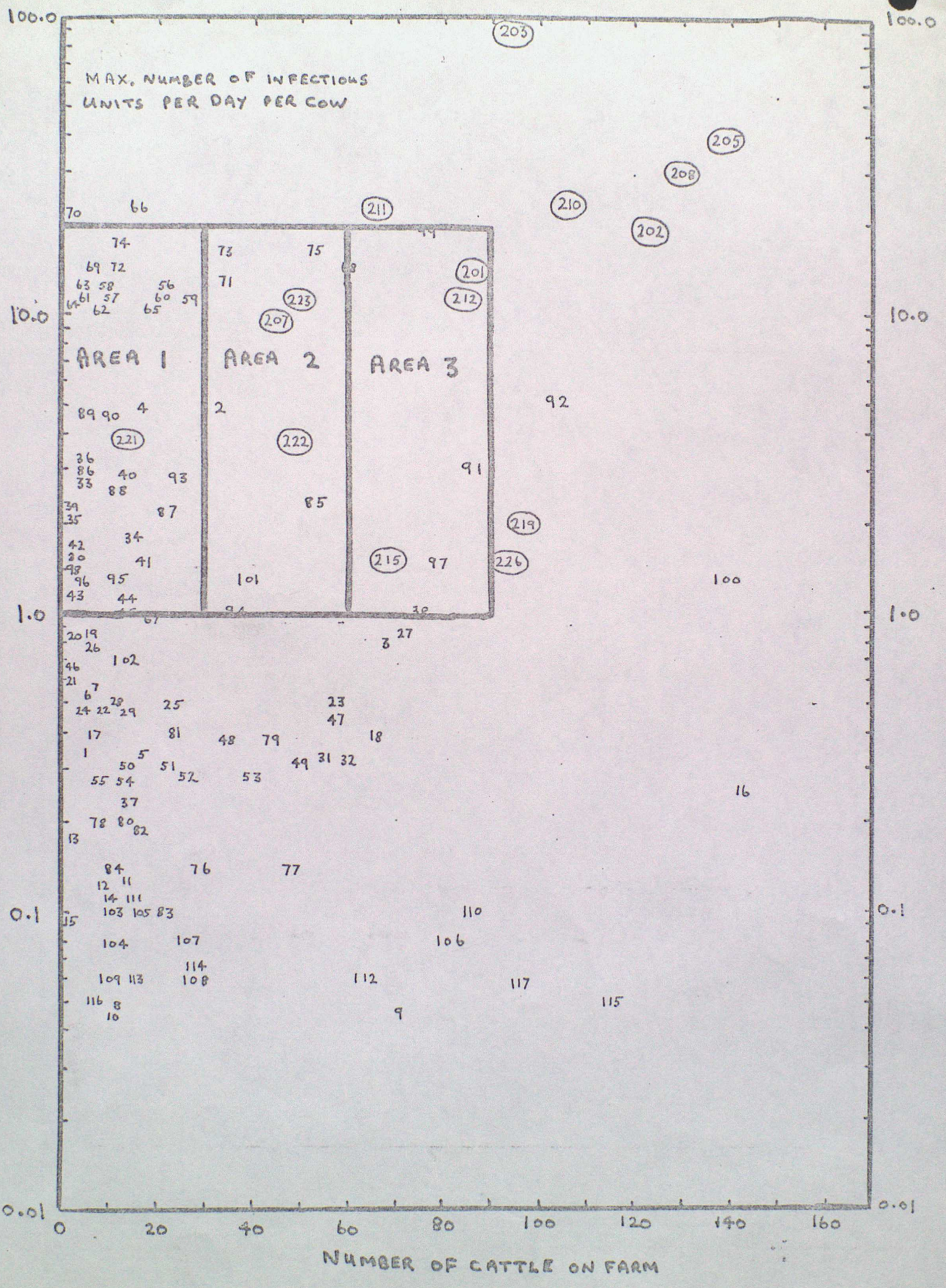


Figure 5. Solution of equation – Lines of equal probability of infection

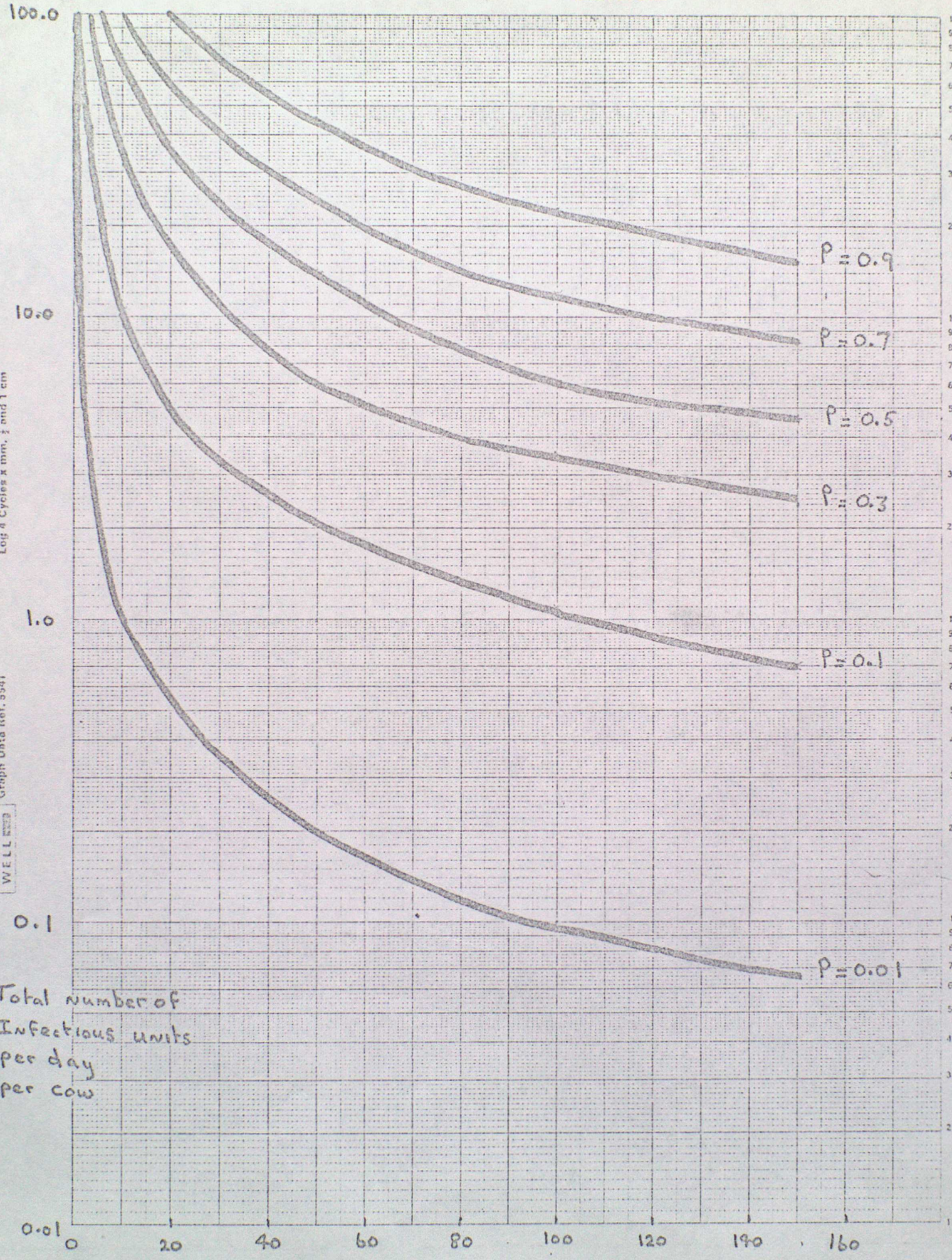


Figure 6 Solution of equation - Lines of equal probability of infection (assuming a threshold value of 1 infectious unit per day per cow)

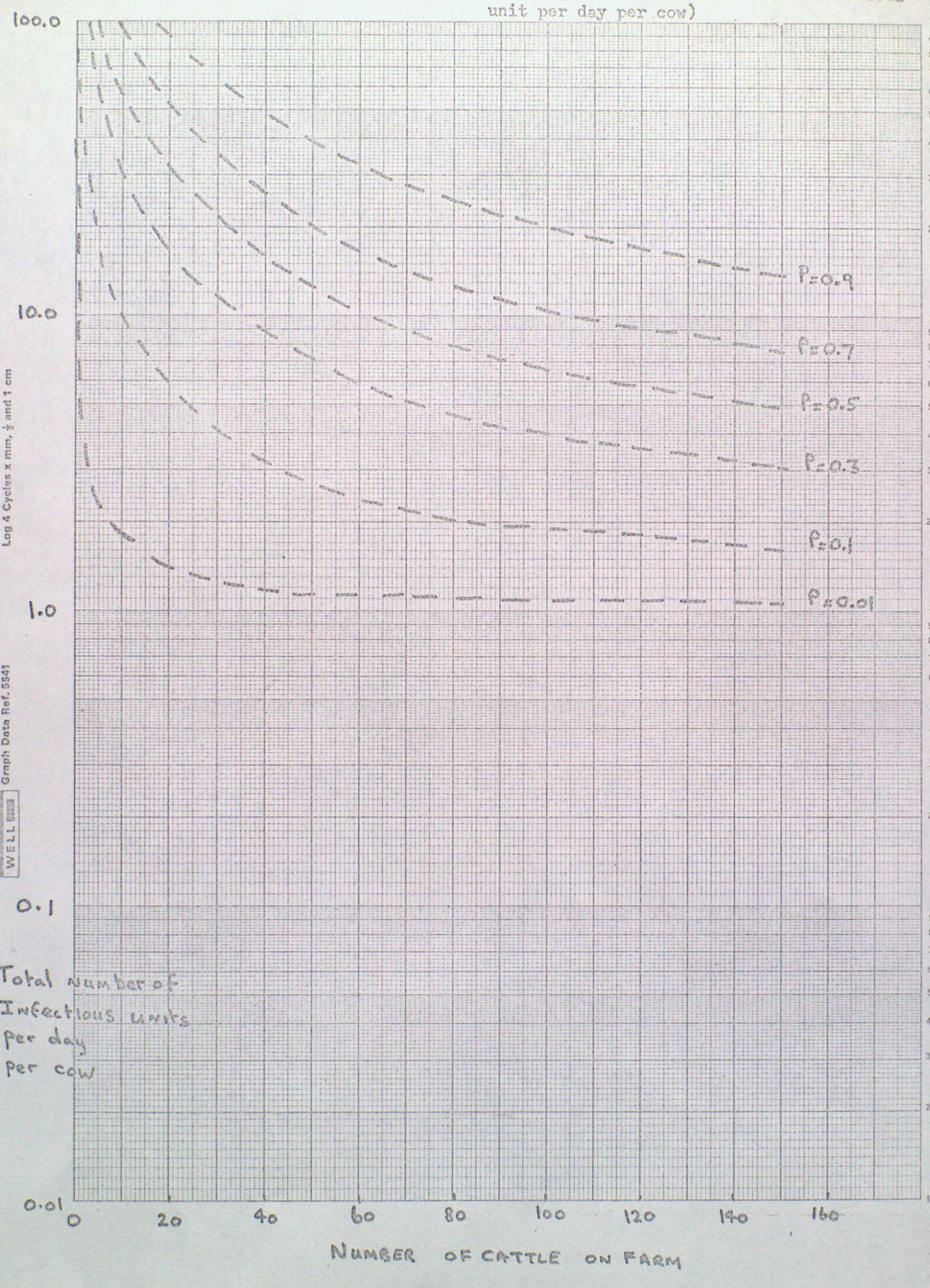


Figure 7 Probability of infection applied to the Hampshire epidemic

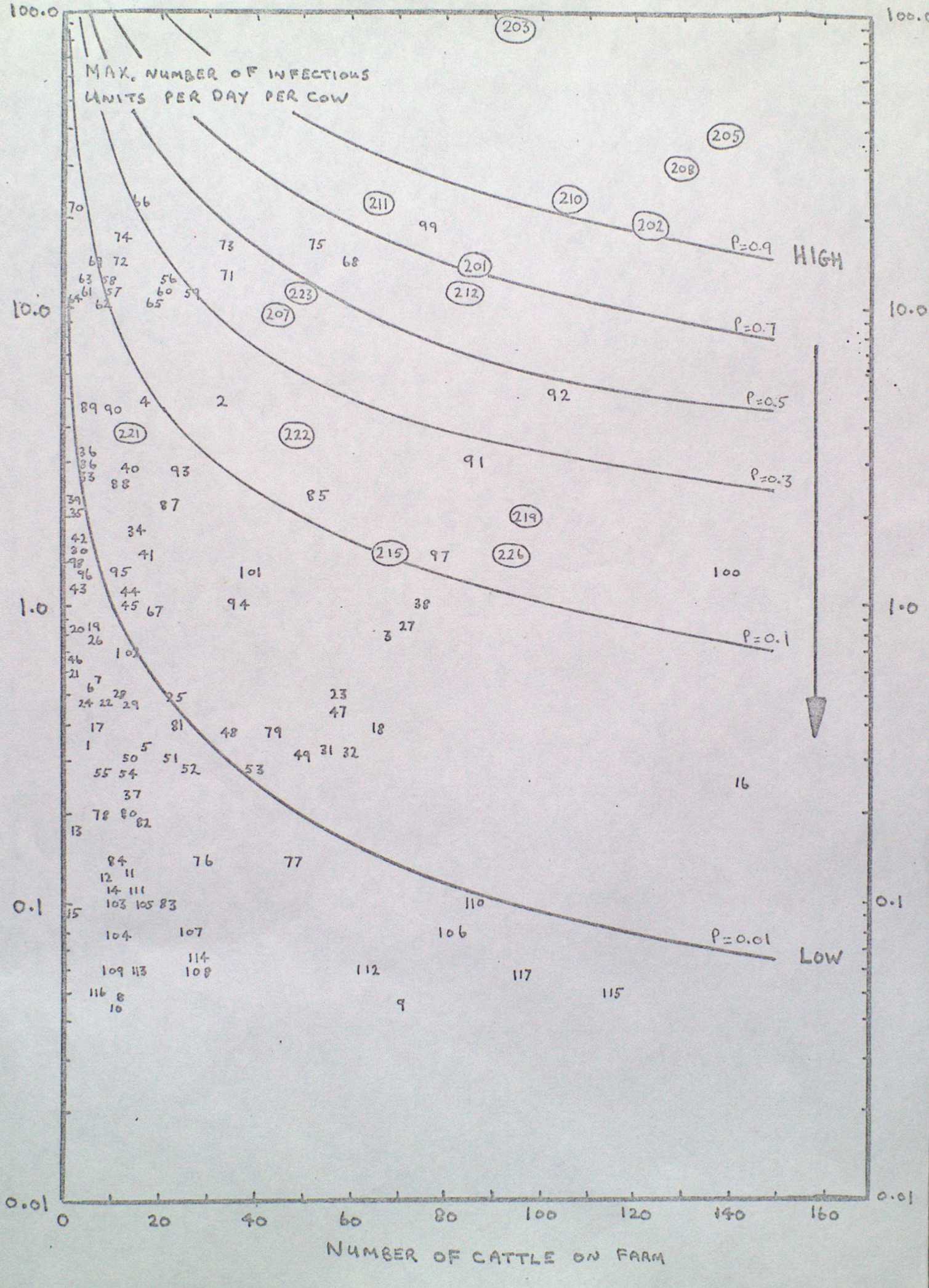


Figure 8 Probability of infection applied to the Hampshire epidemic (assuming a threshold value of 1 infectious unit per day per cow)